Bulging Assessment of Coke Drums
A State-of-the-Art Review

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Coke Drum Bulging

Courtesy of CB&I
Bulging Assessment

- How bad is bulging?
- Where to expect cracking? Inside/outside?
- When to expect cracking?
- Need long-term repair? How?
History

I. Geometric features 1990-

II. Stress concentration factors 1996-

III. API 579/ASME FFS assessment 2001-

IV. Geometric pattern recognition 2003-2011

V. Calibrated Plastic Strain Analysis – Plastic Strain Index (PSI): 2011-
Geometric Features

1) Bulging magnitude
2) Bulge depth / length
3) Sharpness / derivatives

• Advantages
  – Simple

• Disadvantages
  – Not based on solid mechanics
  – Do not relate to any industry standard
  – Have not correlated well with observed cracking
Stress Concentration Analysis

- Linear elastic finite element analysis.
- Drum is built with bulges (no plastic strain).
- Apply design / unit loads.
- Correlates stress intensification to severity.

Advantages
- Simple

Disadvantages
- Unrealistic model (loads, elastic,..).
- Susceptible to significant error sources (ovality, bulge size, aspect ratio, etc..).
- Excludes the primary cause of bulging failure.
Stress Concentration Analysis
Bulging Assessment per API-579 / ASME-FFS

• Level 1: N/A to coke drums
  – Fabrication tolerance.
  – Not for cyclic service.

• Level 2: N/A to coke drums
    No replacement yet.

• Level 3: Infeasible and costly process
  – Lack of proper load definition.
  – Costly to obtain data and simulate bulging.
  – Never done!
Geometric Pattern Recognition

• Database of cracking history.
• Identification of geometric features associated with cracks.
• Commercially unavailable

• Advantages:
  – Excellent correlation with cracking.

• Disadvantages:
  – No basis in mechanics.
Calibrated Plastic Strain Analysis

Local and global distortions

Calibrated using actual failures
Plastic Strain Index (PSI)™

• Ratio of effective plastic strain to failure limit of API 579/ ASME FFS Standard.
• Calibrated using database of actual failures
• Excellent correlation with bulging-induced cracks.
• 300 assessments.

<table>
<thead>
<tr>
<th>PSI magnitude</th>
<th>Severity Grade</th>
<th>Likelihood of Bulging-Induced Cracks</th>
<th>Recommended Frequency of Laser Scanning</th>
</tr>
</thead>
<tbody>
<tr>
<td>80% to 100%</td>
<td>Failure</td>
<td>Likely</td>
<td>6 months to 1 year</td>
</tr>
<tr>
<td>60% to 80%</td>
<td>Danger</td>
<td>Probable</td>
<td>1 year</td>
</tr>
<tr>
<td>40% to 60%</td>
<td>Concern</td>
<td>Possible</td>
<td>1 to 2 years</td>
</tr>
<tr>
<td>0 to 40%</td>
<td>Design</td>
<td>Unlikely</td>
<td>2 to 3 years</td>
</tr>
</tbody>
</table>
Plastic Strain Index (PSI)™
Comparison of Bulging Assessment Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Geometric Features (magnitude, derivatives, sharpness, etc.)</th>
<th>Stress Concentration</th>
<th>Full API 579 Procedure</th>
<th>Pattern Recognition</th>
<th>PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on laws of solid mechanics</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Uses API 579 industry standard limits</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Uses realistic thermomechanical loads</td>
<td>N/A *</td>
<td>NO</td>
<td>NO</td>
<td>N/A *</td>
<td>N/A *</td>
</tr>
<tr>
<td>Calibrated using database of both external and internal failures</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Assessment specifies external versus internal failure initiation</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Correlation to observed failures published by operating companies</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Effectiveness of bulge repairs published by operating companies</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

* N/A: Not Applicable
Where Do We Stand?

**CAN**

- Determine likelihood of bulging-induced cracks
- Determine optimal laser scanning interval
- Determine need for long-term repairs

**CANNOT**

- Determine likelihood of weld-related cracks
- Predict bulging initiation time
- Predict bulging initiation location
- Predict bulging growth
RECAP

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